LHC Collimation Review 2013

Main focus:

- need for warm DS collimators / short 11T dipoles
- assessment of performance reach

Review Committee:

Giorgio Apollinari (FNAL), Wolfram Fischer (BNL), Marzio Nessi (ATLAS), Carsten Omet (GSI), Rudiger Schmidt (CERN/ESS), Mike Seidel (PSI, Chair).

Charge of the review panel:
The committee should look into the various aspects of the presented upgrade baseline and advise in particular on the need to pursue R&D on 11T dipoles for a possible installation in the LHC for LS2. Are the assumptions for performance reach estimates appropriate and adequately addressed?

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- Is the present upgrade strategy appropriate in view of being able to take a decision in 2015?
- Is there any aspect that has been overlooked?

General comments

- Since 2011 the collimation system has demonstrated an excellent performance for beam cleaning but also in view of the operational reliability.
- The committee is impressed by the quality and amount of work performed in different areas, to name some:
  - quench tests with provoked proton losses give important information and show some margin extrapolated to design energy and intensities
  - Collimator jaws with Integrated BPMs
  - status of 11T dipole magnet (CERN/FNAL), and bypass cryostat prototype
  - FLUKA modelling of E-deposit
  - optimization of automated setup procedures for many collimator jaws during run
  - material tests with beam; investigation of new materials

Assessment of performance reach

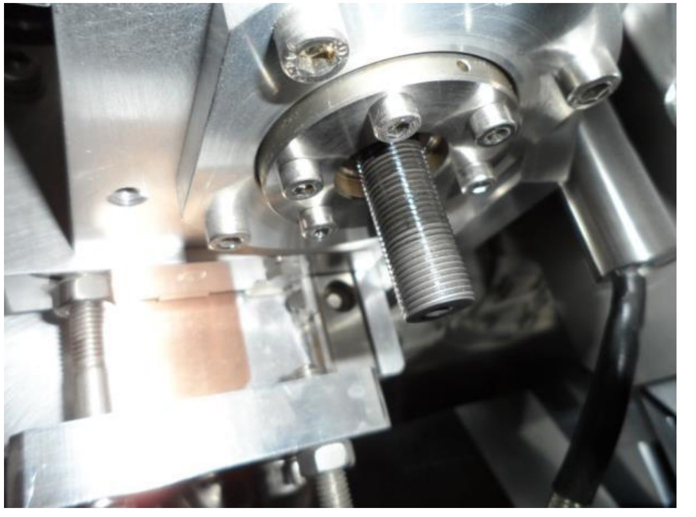
- The quench test at 4 TeV provides a foundation for estimating the performance reach at 7 TeV and suggests sufficient margin. However, extrapolation to 7 TeV is difficult, e.g.:
  - 25 ns bunch spacing
  - Increased impedance may require relaxed collimator settings
  - Reduced beam lifetime due to other reasons
- Without DS collimation in the experimental IRs the heavy ion peak luminosity is expected to be limited to $3x10^{27}$ $cm^{-2}s^{-1}$ while the peak luminosity goal after LS2 is $6x10^{27}$ $cm^{-2}s^{-1}$ (for ALICE only?)

11 T Magnet Comments

- First Nb_3Sn coil to be produced soon at CERN. 9 coils were produced and 2 magnets tested at FNAL. Magnet quality for accelerator operation from injection to flattop appears to be within reach. Remaining issues include:
  - Decision on final mechanical design
  - Damage to conductor and ?related? «holding quenches» problems
  - Long training curve
- Nb_3Sn is a demanding technology. Recent experience shows that it takes 10-20 coils before a performing magnet can be produced. Learning curve appears to be 2-3 years.
- QXF and 11 T may be conflicting on resources but are synergetic in intellectual achievements.
- Field quality for the long 2-in-1 magnet needs to addressed.

Further findings 1

- Operating experience has shown that the movable **collimator mechanics** (roller type bearings) are subject to wear (usual for every movable mechanics system). Furthermore, the used lubricant has been tested for radiation damage, but possibly does not withstand the higher temperatures during bakeout.
- Radiation damage of jaw material can lead to swelling $\rightarrow$ uneven surface $\rightarrow$ efficiency degradation.



Further findings 2

- **Impedance** of the collimators is an issue for beam stability. This will be even more important when intensity and energy is increased further.
- The committee notes that Mo coating of Mo-graphite jaws with 50 μm decreases the impedance by a factor of about 10.
- This is a promising option for reducing the impedance of the collimation system. By the coating of only a small fraction of all jaws the impedance of the machine can be reduced significantly. However, metallic coating reduces the robustness of the system

Recommendations 1

- The committee strongly encourages the development and prototyping of a 11 T (5.5 m) dipole magnet, and the cyro-bypass/collimator unit.
- Build at least 4 units (1 unit consists of 2 magnets + bypass + collimator) since this would cover 2 possible cases:
  - either 2 units in IR2 for ion operation (and 2 spares), or
  - 4 units in IR7 for proton operation
- For LS2 deployment serial «learning curves» of making coils at CERN and later in EU industries cannot be accomodated. The committee agrees with the early involvement of industrial partners.
- Make full use of knowledge acquired in the Nb_3Sn dipole and quadrupole programs to support each other.

Recommendations 2

- The committee believes that all information is available to decide on **length and material of the collimators**. We encourage the teams involved in the studies to discuss the different aspects (efficiency of the cleaning for protons/ions, implications on integration and ongoing design work) and to conclude soon
- To reduce impedance and in turn enhance beam stability, one should
  - Proceed with further studies on the proposed thin Mo coating to verify its mechanical stability during beam impacting with gracing angles of incidence
  - study e.g. asymetric collimator jaw settings
- Address implications of jaw material and coating on machine protection (failure modes leading to lost bunches on these jaws).

Recommendations 3

- Study alternative options to the DS collimators that provide a reduction of the energy deposition by about a factor of 2, possibly sufficient for operation with ions
  - Distributing the energy deposition in the magnet by using dynamic orbit bumps
  - Installation of a thicker beam screen compatible with the aperture inside the vacuum chamber

Recommendations 4

- The quench tests that were performed demonstrate that it is essential to calibrate the complex theoretical models (using particle tacking, hadron shower codes and quench codes) with experimental data.
- Complete the analysis of these tests with the objective of a coherent understanding of the quench limits as a function of loss duration.
- Perform quench tests at high energy, e.g. 6.5 TeV, as soon as possible after the restart of LHC in 2015, including tests with ions.

Recommendations 5

- Mechanical wear of the roller type bearings imposes a risk for unnecessary machine downtime, so it has to be solved.
- **Implementation of a suitable maintenance plan** (such as regular re-lubrication to maintain movable mechanics).
- A long-lasting solution for the future operation is needed. This may include the modification of the drive design to e.g. encapsulate the moving parts or brush away dust on screws automatically.
- The lubricate has to be qualified for compliance to the high temperatures during bakeout.
- Inspection of a primary collimator that has seen high losses would give important information, eg. quality of surface.

Recommendations 6

- Investigate the interplay of luminosity leveling via β^* with the settings of the collimator system; possibly this provides extra safety margin due to relaxed conditions in the early phase of a run.
- Continue studies of halo formation mechanisms and halo cleaning techniques (eg with hollow electron beam).

summary on charge

1. Are the assumptions for performance reach estimates appropriate and adequately addressed?
   Yes, with uncertainties in scaling to 7 TeV operation.
2. Is the present upgrade strategy appropriate in view of being able to take a decision in 2015?
   Yes, see findings and recommendation.
3. Is there any aspect that has been overlooked?
   Did not find any show-stoppers.